GaN Thin Film Grown by Reactive Close-Spaced Method at 750℃

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1. Introduction

Gallium Nitride(GaN) is one of the most promising materials for use in wide-gap semiconductors devices such as blue light-emitting diodes and lasers. GaN films has been grown by the metalorganic chemical vapor deposition (MOCVD) method. Much progress has been achieved in the crystallinity of GaN film. In this study, GaN thin films were grown by direct reaction of Ga and NH_3 at 750℃ by reactive close-spaced configuration.

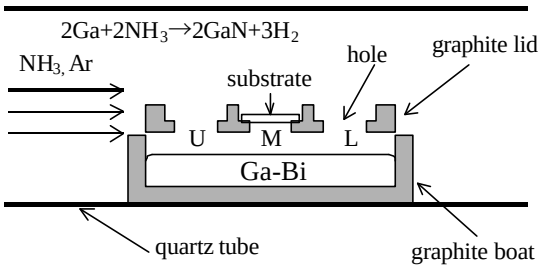

Fig.1. Schematic principle figure of the reactive close-spaced method

2. Experimental Procedure

Ga-Bi alloy and ammonia (NH_3) were used as Ga and N sources. Figure.1 shows the schematic principle figure of the reactive close-spaced method. The source of Ga was diluted with Bi intending to reduce the transport rate of Ga. The alloy of Ga-Bi was charged in a graphite boat with a graphite lid where three holes were covered with substrates. The substrates positions is called U(upper), M(middle) and L(lower) in order of the gas flow direction. Sapphire with (0001)-surface (c-face) was used as substrates. GaN thin films were grown directly on sapphire without GaN buffer layer. After the substrate temperature was reached at 750℃, NH_3 and Ar flew into the quarz tube under 10 Torr for 6 hours. The flow rates of NH_3 and Ar-carrire gas were kept 20ccm and 200ccm.

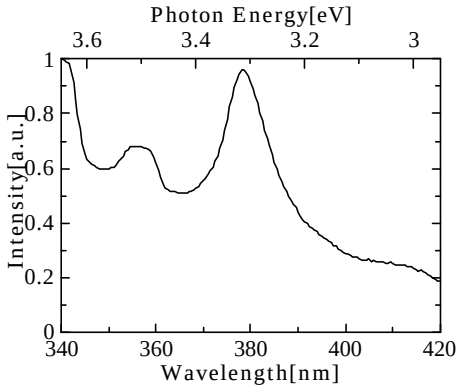

Fig. 2. PL spectra of GaN thin film grown at 750℃ with one substrate (12K)

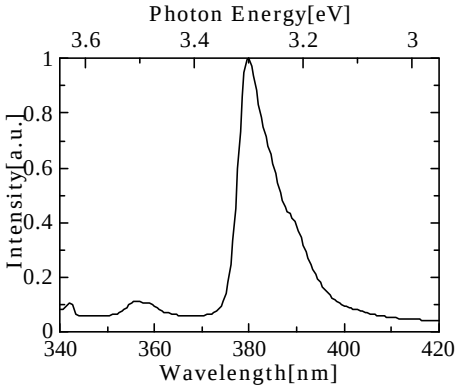

Fig. 3. PL spectra of GaN thin films grown at 750℃ with three substrates (12K)

3. Results and Discussions

GaN thin films were grown by the reactive close-spaced method at 750℃ under low presure. In the run with one substrate put at the position-M in the graphite lid, the thickness of the film grown was 0.1μm. The carrier concentration and Hall mobility of the film were $2\times10cm^{-3}$ and $9cm^2/(Vs)$. The PL spectra of the film have donor-acceptor pair (DAP) emission band peaking at 3.25eV as shown Fig.2. In the run with three substrates put at the position-U, -M and -L in the graphite lid, the thickness of the three films grown were 0.1μm. The carrier concentration and Hall mobility of the films were $4\times10^{19}cm^{-3}$ and $30cm^2$ /(Vs). The PL spectra of the three films have donor-acceptor pair (DAP) emission band as shown Fig.3. In the run with one and three substrates, the films grown showed the properties in the PL spectra with main DAP emission band. The PL spectra of the films have no neutral donor bound emission

(I_2 line) peaking at 3.5eV. It seems reasonable to conclude that high crystalline h-GaN cannot be deposited by direct reaction between Ga and NH_3, because NH_3 isn't decomposed into nitrogen at 750℃ enough to be grown high crystalline h-GaN.

In comparison with the films grown by the reactive close-spaced method at 950℃ under atmospheric pressure, in the run with one substrate, the thickness of the film grown was 0.1 μm. The carrier concentration and Hall mobility of the film were $8\times10^{20}cm^{-3}$ and $6cm^2/(Vs)$. The PL spectra of the film having DAP emission band as shown Fig.4 looks like that of the film grown at 750℃ with one and three substrates. From the result, Ga and NH_3 were not fully reacted on the substrates. Because NH_3 flows between the Ga-Bi alloy and one substrate through the two holes (the position –U and –L) and NH_3 flow removes from evaporated Ga before high crystalline h-GaN thin film were grown by reaction of Ga and NH_3. And the FWHM of the DAP emission band of the thin film grown at 750℃ with three substrates was narrower than that at 950℃ with one substrate. On the other hand, in the run with three substrates, the thickness of the three films grown were 0.1 μm. The carrier concentration and Hall mobility of the films were $1\times10^{21}cm^{-3}$ and $6cm^2/(Vs)$. The PL spectra of the film have two emission bands as shown Fig.5; one is I_2 and the other is DAP emission band along with several LO phonon replicas were slightly seen. The result clearly shows that Ga and NH_3 were fully reacted on the substrates because of NH_3 flow velocity in the area of the Ga-Bi alloy and three substrates help being grown the high crystalline h-GaN.

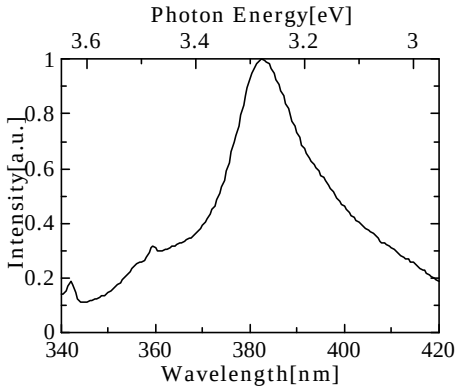

Fig. 4. PL spectra of GaN thin films grown at 950℃ with one substrate (12K)

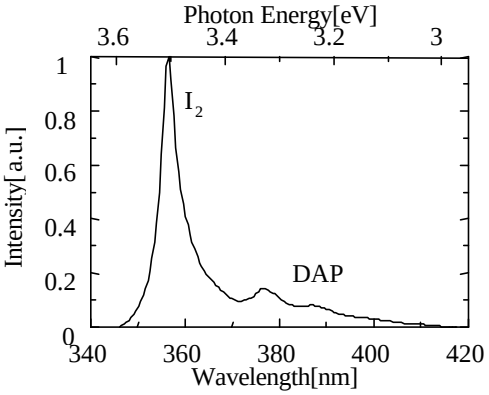

Fig. 5. PL spectra of GaN thin film grown at 950℃ with three substrates (12K)

4. Summary

Turning now to the films grown with three substrates at 950℃ under atmospheric pressure, NH_3 is decomposed into nitrogen enough to be grown high crystalline h-GaN. But in the run with one substrate, the films grown showed the properties in the PL spectra with DAP emission band. On the other hand, in the run with threes substrates, the films grown showed the properties in the PL spectra with I_2 line. Thus in the run with three substrates, the rate of NH_3 flow velocity and the quantity of evaporated Ga are moderate to be grown for high crystalline -GaN by reaction of Ga and NH_3 on the substrate.

GaN thin films were grown at 750℃. The growth pressure needs to be higher than 10Torr in order that NH_3 flow velocity between the Ga-Bi alloy and theree substrates lowers for full reaction of Ga and NH_3 on the substrates. And thermal decomposition of NH_3 is a sluggish reaction at 750℃.It can be accelerated with various catalysts, e.g., Pt and W. Therefore, if GaN thin films were grown at 750℃ under higher than 10Torr with the configuration of the plate of Pt or W putting over the position-U and -L, the substrates putting over the position-M, high crystalline h-GaN could be grown.